EXPLORE!

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Activity: Deep Impact: Making Impact Craters!

Level: Grades 5-8

To Take Home: Crater diagrams

Background Information

Impact Cratering

The impact of asteroids, comets, and meteoroids onto the surfaces of planets is a major geologic process. Craters are roughly circular, excavated holes made by impact events and are the most common features on many planets and satellites. The structure of impact craters is more complex in larger craters. Larger craters collapse, forming terraces, central peaks, central pits, or multiple rings. Although craters are similar on most of the planets, there are important differences. Most of these differences are related to the presence of ice in the crusts of bodies like Mars and the icy satellites (moons) of planets in the outer solar system.

Rock material excavated (or thrown out) of the crater is called ***ejecta.*** This ejecta is distributed outward from the crater's center onto the planet's surface as debris. Bright streaks of this material spreading radially outward from the crater are called rays. The size and shape of the crater and the extent of the ejecta is based on several factors, including the mass and velocity of the impacting body and the geology of the planet surface. The planet's surface can affect the way a crater is formed. The strength of the planet's surface material, the composition of the rock, the presence of water, and its gravity will all affect the final shape of the crater. Very large impact craters are called ***impact basins.***

Scientists record the number, size, and extent of erosion of impact craters on a planetary body to determine the ages of different surfaces and figure out the geologic history of the object. This technique works because older surfaces are exposed to impacting bodies (meteoroids, asteroids, and comets) for a longer period of time than younger surfaces.

Major Parts of a Crater

Floor - The bottom of a crater, either bowl shaped or flat, usually below ground level, sometimes filled in with lava or other material.

Central pits - A depression found in the central area of the floor of a crater possibly caused by the presence of ground ice. Found in craters a few tens of kilometers across on Mars and some of the icy satellites.

Central peaks - A mountain formed in the central area of the floor of a large crater. For larger craters (typically a few tens of kilometers in diameter) the excavated hole becomes so great that it collapses on itself. Collapse of the hole pushes up the mound that forms the central peak.

Walls - The interior sides of a crater, usually steep. They may have giant stairstep faults called terraces that are created by slumping due to gravity.

Rim **–** The edge of the hole formed by the impact is called the rim. It is actually elevated above the surrounding terrain because it is composed of material thrown out of the crater during excavation.

Ejecta - Material thrown out of the crater area during an impact event, or a blanket of debris surrounding the crater, thinning at the outermost regions. Fluidized ejecta (mixed with fluid) has been seen on Mars and may be due to the presence of ground ice.

Rays **-** Bright streaks extending away from the crater sometimes for great distances, composed of ejecta material.

Types of Craters

Simple Craters - Bowl-shaped, smooth-walled craters of a small size (as with central peaks, the size limit depends on the planet).

Pit Crater - An impact crater containing a central depression rather than a central peak. Also called a central pit crater.

Complex Craters **-** Larger craters with more complicated morphology. Larger craters can collapse, form terraces, central peaks, central pits, multiple rings and peak ring basins.

Impact Basins - Very large (over 300 kilometers in diameter) impact structures are usually called impact basins rather than craters. The largest impact basin on the Moon is 2,500 kilometers in diameter and more than 12 kilometers deep. Large impact basins also are found on other planets, including Mars and Mercury.

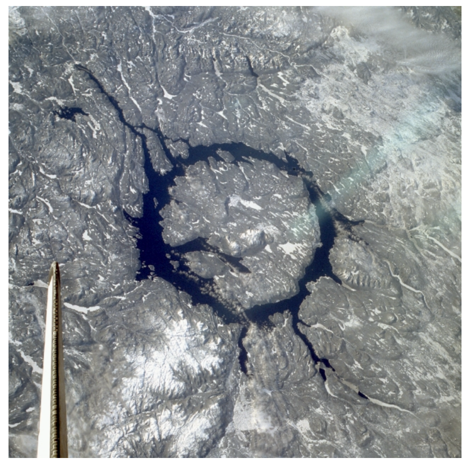
Peak Ring Basins - A large impact basin featuring a ring of massifs (mountains) on the basin floor.

Multi-ring Basins - A very large impact basin surrounded by as many as 5 or 6 circular rings of mountain chains in addition to the main basin rim.

Irregular Craters - Craters with irregular shapes or multiple impact craters formed at the same time.

Degraded Craters - Craters that have become eroded due to weathering, lava flows, impacting, or downslope movement of material.

Terrestrial Craters



Manicouagan Impact Structure, Quebec

On the Earth impact craters are harder to recognize because of weathering and erosion of the planet's surface. Famous impact craters on the Earth are Barringer (or Meteor) Crater in Arizona, Manicouagan Crater in Quebec, Sudbury Crater in Ontario, Ries Crater in Germany, and Chicxulub Crater on the Yucatan Peninsula in Mexico. The Chicxulub Crater in Mexico is considered by most scientists to be the source crater for the impact that led to the extinction of the dinosaurs 65 million years ago. One interesting feature about this crater is that it cannot be seen on the surface–its circular structure lies a kilometer below newer sediments, partially under the ocean. It was originally identified from highly disrupted rock fragments found while drilling for oil in the region.

Barringer (Meteor) Crater, Arizona

Barringer or Meteor Crater in Arizona is one of the youngest and best-preserved impact craters on Earth. The crater formed roughly 50,000 years ago when a 50-meter-wide iron-rich meteor weighing 100,000 tons struck the Arizona desert at more than11 kilometers per second. The resulting explosion exceeded the combined force of today's nuclear arsenals and created a 1.1-kilometer-wide, 200-meter-deep crater. Meteor Crater is a simple crater since it has no central peak or rim terraces.

Lunar Craters

Both the Earth and the Moon are the targets of a continuing bombardment of meteoroids, asteroids, and comets from outer space. The "shooting stars" that are commonly seen in the night sky are mostly dust-sized objects striking the Earth's atmosphere. Much more rarely, larger objects sometimes strike the Earth or Moon producing craters. Over its history, the Moon has had countless millions of craters form on its surface. The Moon features impact craters from millimeters to thousands of kilometers in diameter. In general, lunar impact structures increase in complexity with increasing size, from simple bowl-shaped craters (less than 15 kilometers in diameter), to complex craters, to multi-ring basins (more than 300 kilometers in diameter). Lunar craters are ideally suited for study because the Moon's surface has not been modified by recent geologic activity. The Moon lacks water, an atmosphere, and plate tectonics, three forces that act to erode the Earth's surface and erase all but the most recent impacts. Approximately 80% of the Earth's surface is less than 200 million years old, while more than 99% of the Moon's surface is more than 3 billion years old.

Comets and asteroids strike the Moon at a wide range of impact speeds, with 20 kilometers per second being typical. Such a high-speed impact will produce a crater that is 10 to 20 times larger in diameter than the impacting object! The form of the crater depends on its size. The *Crater Diagram* handout shows cross sections of the structure of small, simple craters (top) and of larger, more complex craters (bottom). Simple craters have bowl-shaped depressions and are the typical crater form for structures on the Moon. Craters on the Moon with diameters larger than about 15 kilometers have more complex forms, including shallow, relatively flat floors, central uplifts, and slump blocks and terraces on the inner wall of the crater rim. In craters on the Moon with diameters between about 20 and 175 kilometers, the central uplift is typically a single peak or small group of peaks. When impact structures exceed 300 kilometers in diameter, they are termed impact basins rather than craters. More than 40 such basins are known on the Moon.

Much of the material ejected from the crater is deposited in the area surrounding the crater. Close to the crater, the ejecta typically forms a thick, continuous layer. At larger distances, the ejecta may occur as discontinuous clumps of material. Some material that is ejected is large enough to create a new crater when it comes back down! These new craters are termed ***secondary craters*** and frequently occur as lines of craters that point back to the original crater. Material below the surface of the crater is significantly disrupted by the shock of the impact event. Near the surface is a layer of ***breccia*** (a type of rock composed of coarse, angular fragments of broken-up, older rocks). Rocks at deeper depths remain in place (termed bedrock) but are highly fractured by the impact.

<u>Making Impact Craters</u>

The Impact Crater activity is fun to do and relatively inexpensive. It involves using a box containing layers of different colored materials such as sand, white sugar, and powdered paint to represent the surface of planet. Various objects representing impactors will be dropped or thrown into the material in the box to create craters and other impact effects. The ejecta patterns created by the colored paint or sand are dramatic and can be compared with ejecta patterns seen on spacecraft images. Students will measure crater sizes and draw ejecta patterns to see what effects size, weight, velocity, and angle of impact have on the resulting craters.

Activity

Timeframe - 90 minutes

<u>Making Impact Craters</u>

Materials

Safety Glasses

2 or more large tubs or litter boxes

> ***These should be plastic, metal, or cardboard. Do not use glass. They should be at least 7.5 cm deep. Basic 10"x12"aluminum pans or plastic tubs work fine, but the larger the better to avoid misses. Also, a larger pan may allow students to drop more marbles before having to resurface and smooth the target materials.***

Sand or flour
Powdered tempera paint, colored sand, powdered drink mix or white sugar
Small balls of different sizes and weights: marbles, ball bearings, golf balls, ping pong balls
Plastic bags
Small irregularly shaped rocks
Yardsticks or tape measures
Small rulers
Crater diagrams, worksheets, and pencils

<u>Introduction to Craters</u>

Begin by looking at craters in photographs of the Moon and asking students their ideas of how craters formed. **What do you think are factors that affect the appearance of craters and ejecta?** For an examination of actual craters, almost any image of the Moon will do, to prepare the group. Just about all craters have deep central depressions, raised rims, and a blanket of ejected material surrounding them. You and your students can observe the Moon directly during daylight. Check your newspaper for the phases of the Moon and observe it in the afternoon during "first quarter" or in the morning during "third quarter." The Moon will be separated from the Sun by 90 degrees to the east (left) at first quarter and 90 degrees to the west (right) during third quarter. The large dark regions are the remains of very great impacts and many retain their circular boundaries. Binoculars on a tripod provide a spectacular view of lunar craters.

Many students will have seen the impact films recently released by Hollywood. Large impacts of this sort are extremely rare today, although they could happen. Early in the formation of the solar system these large impacts were more common. The "period of heavy bombardment" was caused by the impact of debris from the early formation of the solar system raining in on the newly formed planets. Students may be familiar with one more "recent" large impact, because of its probable link to the extinction of the dinosaurs. This impact happened 65 million years ago creating the Chicxulub crater. This very large crater is partially underwater and partially hidden by forest growth on land but computer-generated images are available to show students. You can also show them pictures of Meteor Crater near Winslow, Arizona. It is 1.2 kilometers (0.75 miles) across and 200 meters (650 feet) deep. It was formed about 49,000 years ago when a 50 meter (150 foot) nickel/iron meteorite struck the desert at a speed of 11 kilometers per second (25,000 miles per hour). Native Americans living in the region observed the impact and felt the tremendous shock wave that moved through the atmosphere.
Timeframe - 30-45 minutes.

Making Craters

Using a variety of different size and weight balls, marbles, etc. students will drop them from three different heights (12, 24, and 36 inches) and examine and measure the craters and ejecta formed. Dropping impactors of different mass from the same height will allow students to study the relationship of *mass* of the impactor to crater size. Dropping impactors from different heights will allow students to study the relationship of *velocity* of the impactor to crater size.

Students can then try throwing them at different angles, with additional force and even (if you are game) using a slingshot. **Always use eye protection (safety glasses).** Students can explore the effects that occur when impactors travel with more velocity, and from a different angle. The ejecta patterns created by the colored paint or sand are dramatic and can be compared with ejecta patterns seen in spacecraft images. Students will measure crater sizes and draw ejecta patterns. After several craters, the flour and tempera can be mixed and re-smoothed without changing the white of the flour too much. Then a new layer of tempera and a new layer of flour (or sand) can be applied and additional experiments conducted. In real impacts the impacting object is destroyed or broken up into small chunks. Of course the marble will not do this and will remain whole in the crater.
Timeframe - 30-45 minutes.

Procedure

1. **Fill the pan with surface (sand or flour) material to a depth of about 2.5 cm.**
2. **Smooth the surface, then tap the pan to make the materials settle evenly.**
3. **Sprinkle a fine layer of dry tempera paint (sugar, powdered drink mix, or colored sand) evenly and completely over the surface. (Use a sieve or sifter for more uniform layering).**
4. **Then sprinkle a fine layer of sand or flour over the top.**
5. **Put one of each type of ball in a plastic bag for each team.**
6. **Make copies of the Data Chart.**

Making Impact Craters safely

Make sure students wear eye protection. Remind them that ejecta will be excavated out of the impact craters and could get in their eyes. During this activity, the flour, sugar or dry paint may fall onto the floor and may even be dispersed into the air. Spread newspapers under the pan(s) to catch spills or consider doing the activity outside. Because of the low velocity of the marbles compared with the velocity of real impactors, the experimental impact craters may not have raised rims. Central uplifts and terraced walls will also be absent. The higher the drop height, the greater the velocity of the marble, so a larger crater will be made and the ejecta will spread out farther. If the angle of impact is changed, then the rays will be concentrated and longer in the direction of impact. A more horizontal impact angle produces a more skewed crater shape.

Procedure

1. **Have students put on their safety glasses!**
2. **Have the students break up into small groups.**
3. **Using the Data Chart to record data, have them drop each of the different weight and size balls from three different heights.**
4. **Have them measure the size of each crater and the length of the ejecta.**
5. **Have them make a drawing of the crater surface they have created.**
6. **Bring the group back together to discuss the relationship of *mass* (or weight) of the impactor to crater size. How did balls of different mass dropped from the same height affect the crater size?**
7. **Discuss the relationship of the *velocity* of the impactor to crater size. How did the different velocities (speeds) of the balls affected the crater sizes?**
8. **Have the students resurface the pans with a new layer of flour or sand and smooth out the top with the edge of their ruler.**
9. **Have students try throwing balls at different angles. Then have them attempt to add more force (or use a sling shot) to make a crater. Then have students try to drop an irregularly shaped rock.**
10. **Bring the group back to discuss the types of craters made using these last three variables.**
11. **What types of craters were formed when the impacts came in at an angle?**

12. What types of craters were formed by the high-speed impactors?
13. What types of craters were formed by the irregular rocks?

Follow Up Discussion

Have the class compare and contrast their hypotheses on what things affect the appearance of craters and ejecta.

To show how you can tell a surface is older by the increased number of craters, use three packed wet sand surfaces and a sprinkler watering can with most of the holes covered. Cover the sprinkler nozzle with tape and poke out 10-12 holes. Then pour the water out of the sprinkler over the first surface for 10 seconds, for the second 20 seconds and for the third 30 seconds. The number of craters made by the water droplets will be greatly increased over time.

Recommended Videos

Meteorites
Vol. 1, *Menace from the Sky*; Vol. 2, *Witnesses from Beyond the Times*
$29.95, Grades 9-12, 84 minutes total, 1993, Total Marketing.com, (800)-469-7977
Through filmed footage of meteorite discoveries throughout the world, computer graphics, and astonishing pictures taken by Voyager II, the videos delve into the many legends, myths, and scientific facts we've been able to gather about these "messengers from outer space." Among the questions explored by the documentary is whether or not the huge meteorite that struck the earth 65 million years ago could have the extinction of the dinosaurs.

Asteroids: Deadly Impact.1997
In this series installment, NASA scientists and other sky watchers consider the possibility of an asteroid's collision with Earth, with accounts of potential NEOs (Near Earth Objects).

Meteors: Countdown to Impact
Features footage of meteors and interviews with experts discussing the possible effects of a large object striking the Earth.

Sudden Impact: Meteors. 1998
Offers images and computer simulations and explores mans fascination with meteors in the past and his concern about them striking the Earth in the future.

Messengers From Outer Space: Part 1, *Menace from the Sky;* Part 2, *Witnesses from Beyond the Times*
2 parts of 45 minutes each, http://www.orf.at.orf/tv.sales/documentaries/page_14a.htm
Reports on the potential danger of meteorites and how we can learn about the origins of our solar system by studying them.

Books you can borrow from your library

Non-fiction

Marsh, Carole and Arthur R. Upgren. *Asteroids, Comets, and Meteors* (Secrets of Space). Twenty First Century Books, 1996. ISBN: 0805044736.

Aronson, Billy. *Meteors: The Truth Behind Shooting Stars* (First Book). Franklin Watts, Incorporated, 1996. ISBN: 0531202429.

Reddy, Frank and Greg Walz-Chojnacki, Isaac Asimov. *Discovering Comets and Meteors* (Isaac Asimov's New Library of the Universe). Gareth Stevens, 1996. ISBN: 0836812301.

Vogt, Gregory. *Asteroids, Comets, and Meteors.* Millbrook Press, 1996. ISBN: 1562946013.

Simon, Seymour. *Comets, Meteors, and Asteroids*. William Morrow & Co. Library, 1994. ISBN: 068812710X.

Posner, Jackie. *The Magic School Bus Out of This World: A Book About Space Rocks* Scholastic Trade, 1996. ISBN: 0590921568.

Rosen, Sidney. *Can You Catch a Falling Star?* (Question of Science) Carolrhoda Books, 1995. ISBN: 0876148828.

Berger, Melvin. *Why Did the Dinosaurs Disappear? The Great Dinosaur Mystery* (Discovery Readers). Ideals Children's Books, 1995. ISBN: 1571020330.

Wood, A. J. *Countdown to Extinction.* Disney Press, 1998. ISBN: 0786831758.

Granowsky, Alvin. *The Dinosaurs' Last Days* (World of Dinosaurs Series). Steck-Vaughn Library Division, 1992. ISBN: 0811432505.

Branley, Franklyn M. *What Happened to the Dinosaurs?* (Let's-Read-And-Find-Out Book). Harpercollins Juvenile Books, 1991. ISBN: 0064451054.

Fiction

Polacco, Patricia. *Meteor!* Philomel Books, 1999. ISBN: 0399233849.

Madelyn Carlisle and Yvette Banek. *Let's Investigate Magical, Mysterious Meteorites.* Barrons Juveniles, 1992. ISBN: 0812047338

Related Internet Sites:

The Nine Planets
http://www.seds.org/billa/tnp/nineplanets.html

Our Solar System
http://athena.wednet.edu/curric/space/planets/

Mars Craters

Mars Global Surveyor Crater Project
http://www.psi.edu/projects/mgs/mgs.html

Moon Craters

Lunar Impact Crater Geology
http://www.lpi.usra.edu/expmoon/science/craterstructure.html

Earth Craters

Terrestrial Impact Crater Slide Set
http://www.lpi.usra.edu/publications/slidesets/impacts.html

This Dynamic Planet
http://pubs.usgs.gov/pdf/planet.html

Terrestrial Impacts
http://gdcinfo.agg.emr.ca/crater/world_craters.html

Barringer Crater
http://www.barringercrater.com/

IMPACT CRATER - DATA CHART

12" DROP	Ball 1 Type:	Ball 2 Type:	Ball 3 Type:	Ball 4 Type:
Crater Diameter				
Crater Depth				
Crater Ray Length (average)				
24" DROP				
Crater Diameter				
Crater Depth				
Crater Ray Length (average)				
36" DROP				
Crater Diameter				
Crater Depth				
Crater Ray Length (average)				

What happened to the craters as you dropped the balls from a higher distance?

____

What happened when you dropped heavier balls?

____

What happened when you changed the angle of impact?

____

What happened when you increased the velocity?

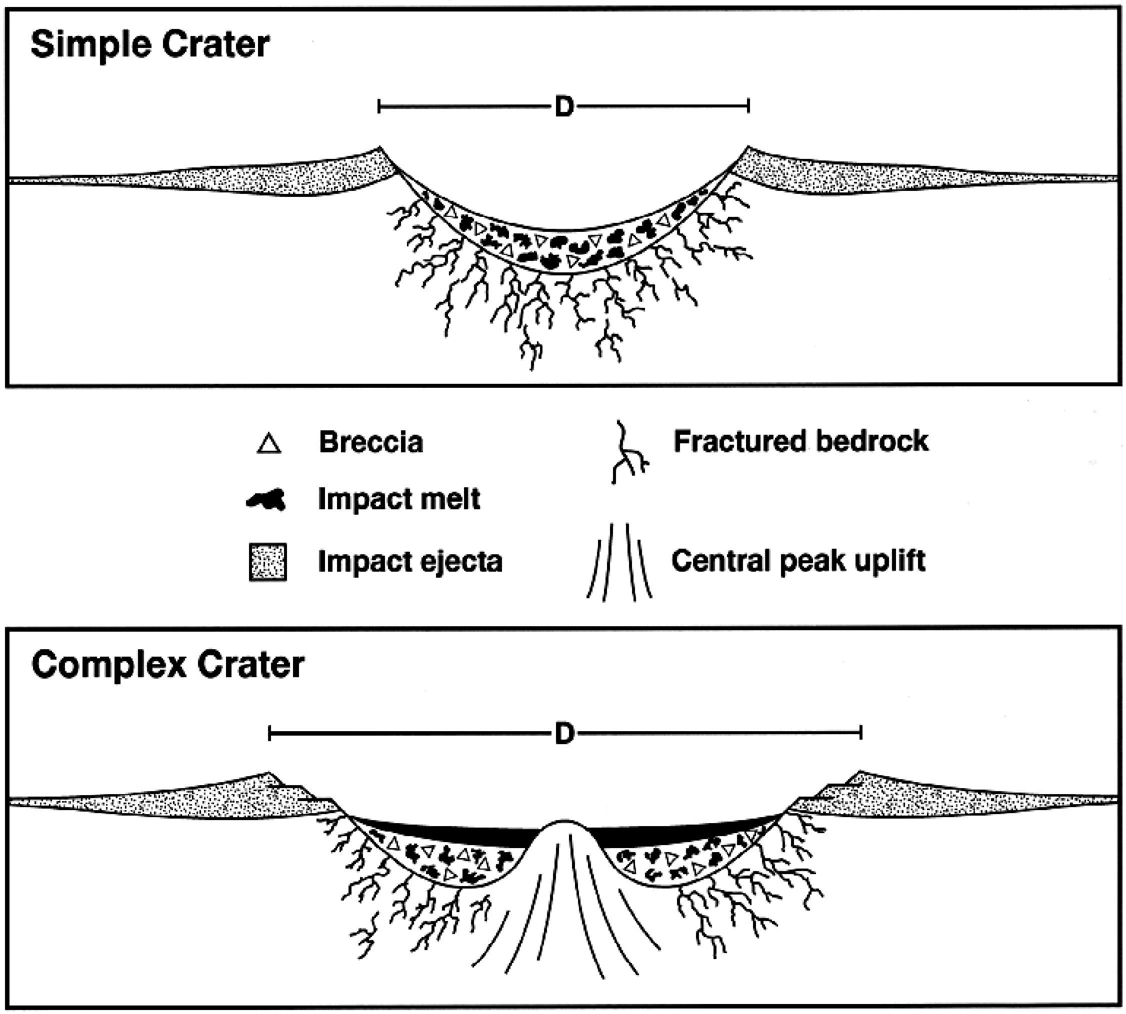
____

What happened when you dropped irregular rocks?

____

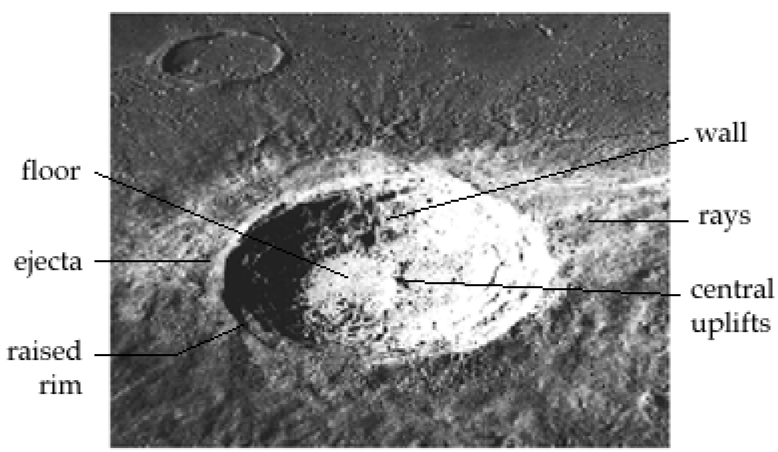
On the back of this chart draw the craters you made on your simulated planetary surface.

CRATER DIAGRAM

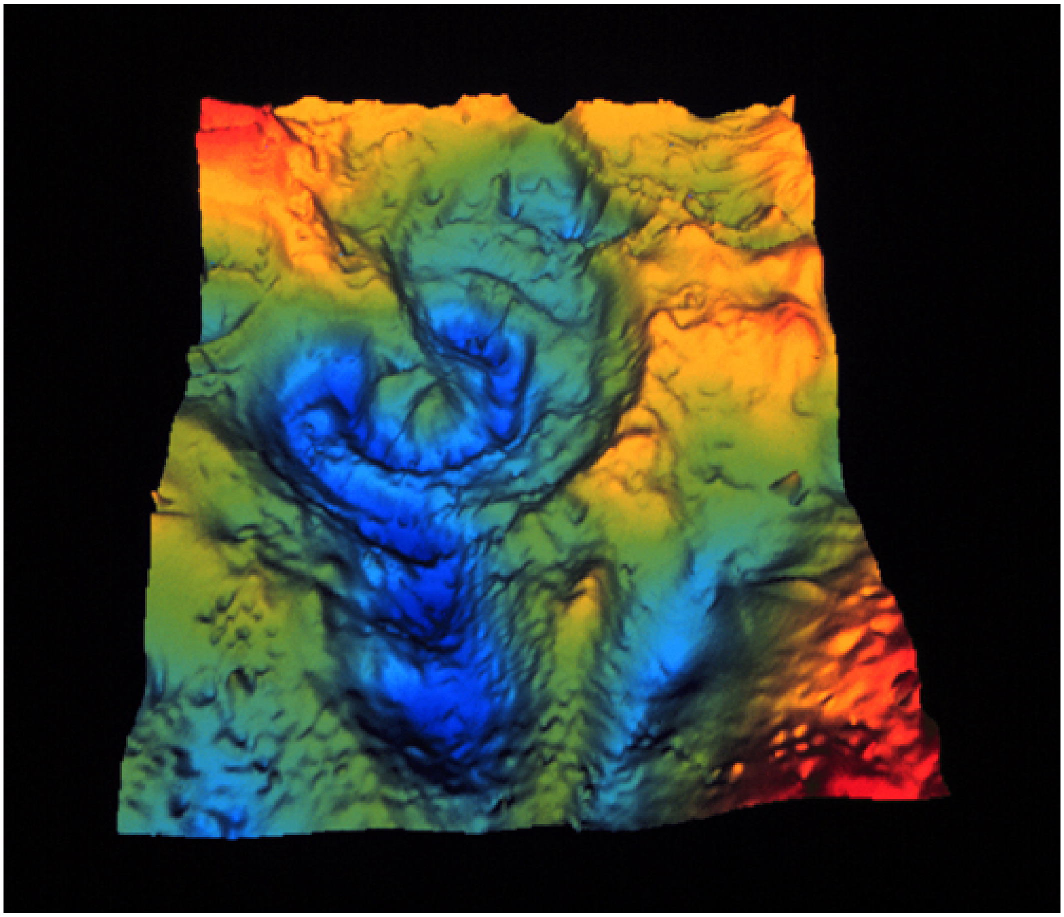


Parts of a Crater

Aristarchus



MOON CRATER



<u>**Chicxulub Crater, Mexico**</u>

This is a computer generated gravity map image of the Chicxulub crater. The buried impact structure has been implicated in the mass extinction of life 65 million years ago and may be much larger than scientists had first suspected. The original Chicxulub crater has been filled with sediments, so the original topographic depression is no longer visible. Because these sediments are less dense (that is, less compacted) than the rocks that surround the crater, the pull of gravity is slightly less over the crater than in the surrounding region. By carefully measuring the force of gravity in different places, we can therefore still "see" where the crater is. The depression shown in the map is the crater.

New analyses of gravity measurements in the region have turned up evidence that the feature is a multiring basin with a fourth, outer ring about 300 kilometers in diameter. At this diameter, the Chicxulub basin represents one of the largest collisions in the inner solar system since the so-called "heavy bombardment" ended almost four billion years ago. (The period of heavy bombardment was caused by the impact of debris from the early formation of the solar system raining in on the newly formed planets.) The only comparable post-bombardment basin is the 280-kilometer-diameter Mead basin on Venus.

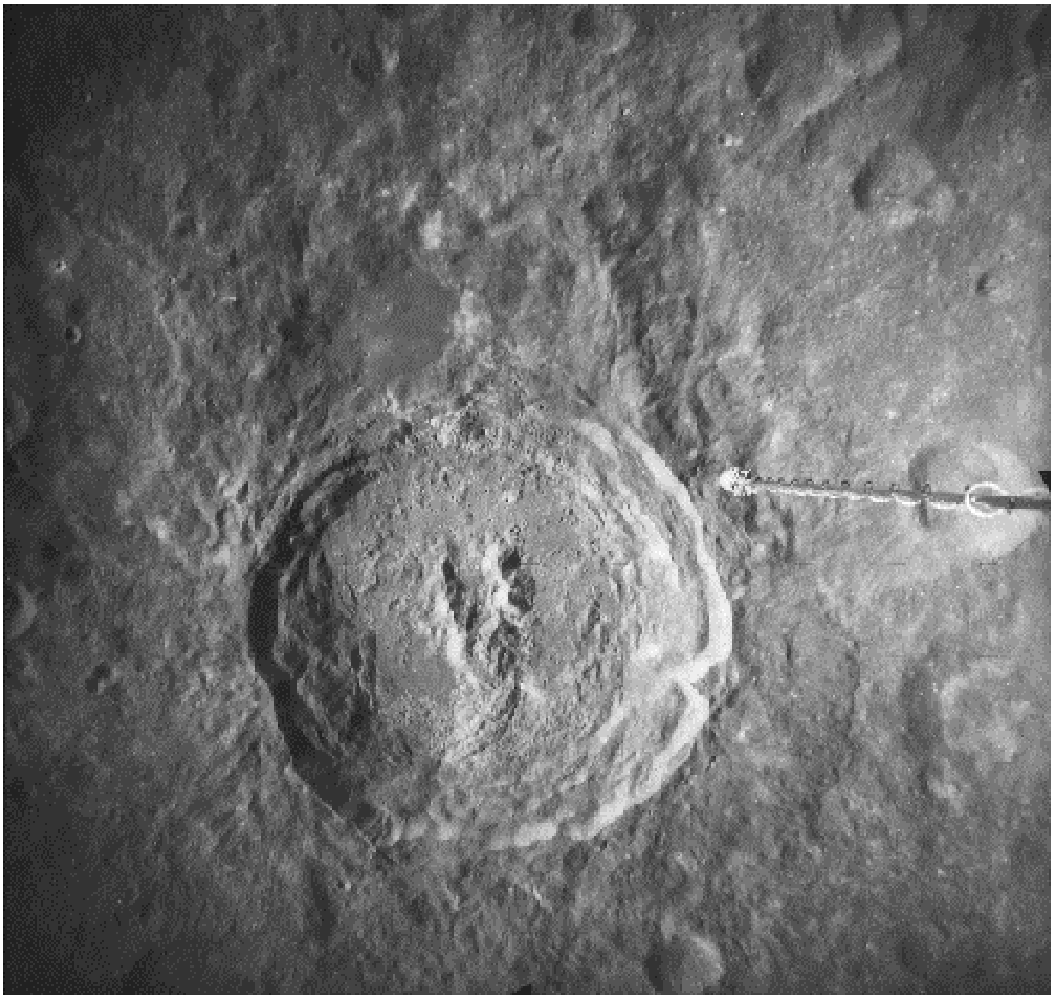
- **Credit: Lunar and Planetary Institute**

Barringer Meteor Crater, Arizona

Meteor Crater is one of the youngest and best-preserved impact craters on Earth. The crater formed roughly 50,000 years ago when a 50-meter-wide iron-rich meteor weighing 100,000 tons struck the Arizona desert at an estimated 20 kilometers per second. The resulting explosion exceeded the combined force of today's nuclear arsenals and created a 1.1-kilometer-wide, 200-meter-deep crater. Meteor Crater is a simple crater since it has no central peak or rim terraces. The crater formed in layered sedimentary rocks, some of which are exposed in the nearby Grand Canyon. These rocks have been uplifted and in some cases overturned at the crater's raised rim. Debris sliding and subsequent erosion have partially filled the bottom of the crater with minor amounts of rim material and sediment.

The heavily cratered history of the Moon indicates that Earth also experienced many impact events early in its history. The processes of erosion and plate tectonics have combined to erase nearly all Earth's craters. To date, only about 150 impact craters have been identified on Earth, and most of those are severely eroded or buried by later rock units. This aerial view shows the dramatic expression of the crater in the arid landscape.

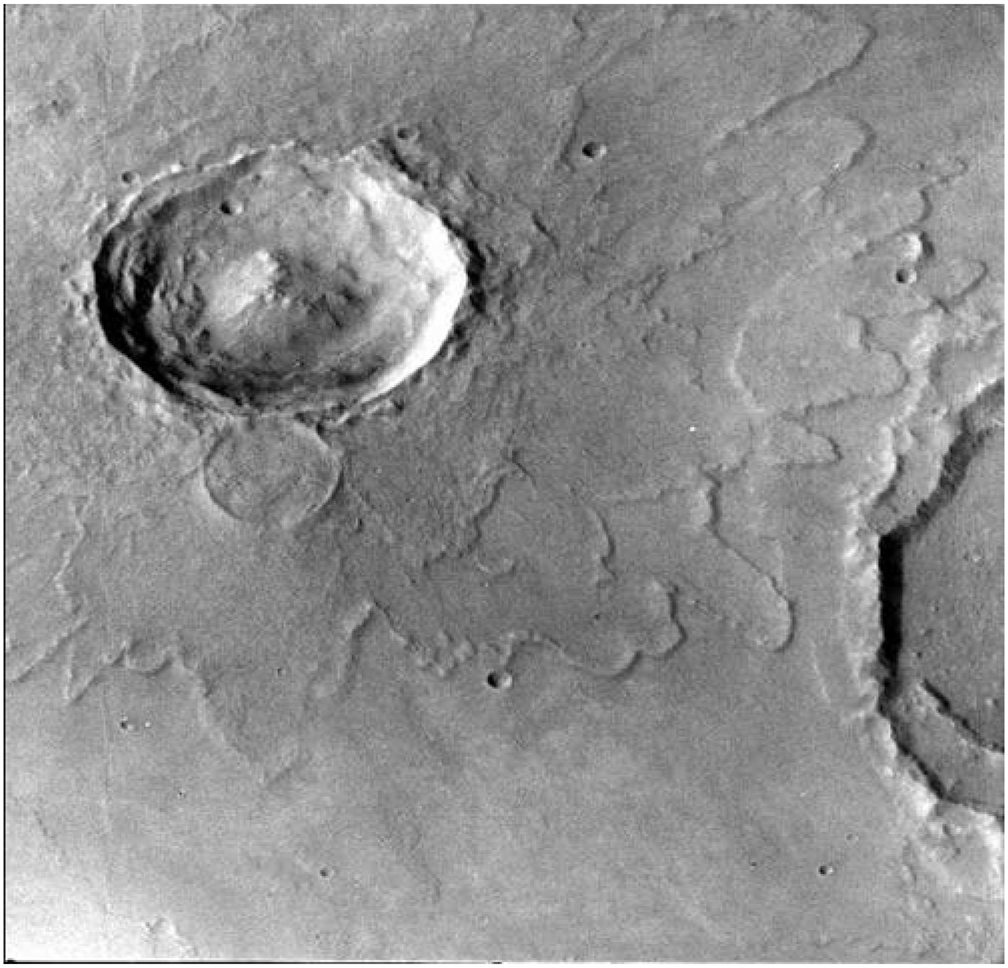
- **Credit: D. Roddy, U.S. Geological Survey**



King Crater

This photograph shows King Crater on the Moon's farside and was taken by the Apollo 16 astronauts in April, 1972. King Crater is 77 kilometers in diameter and more than 5 kilometers deep. It is the freshest crater in this size range on the farside of the Moon. Its overall form is generally typical of large lunar craters. The floor of the crater is relatively flat in places and has numerous small hummocks in other places. The central peak has a complex, Y-shaped form and is larger than normal for a crater of this size. The inside of the crater rim contains a series of terraces and slump blocks. Just north of the rim there is a dark, flat patch of ground that formed where molten material ponded in an old, degraded impact crater. This material might have been melted by the impact that formed King Crater; alternatively, it has also been suggested that it formed volcanically. One of the spacecraft's instrument booms is visible on the right side of the photo.

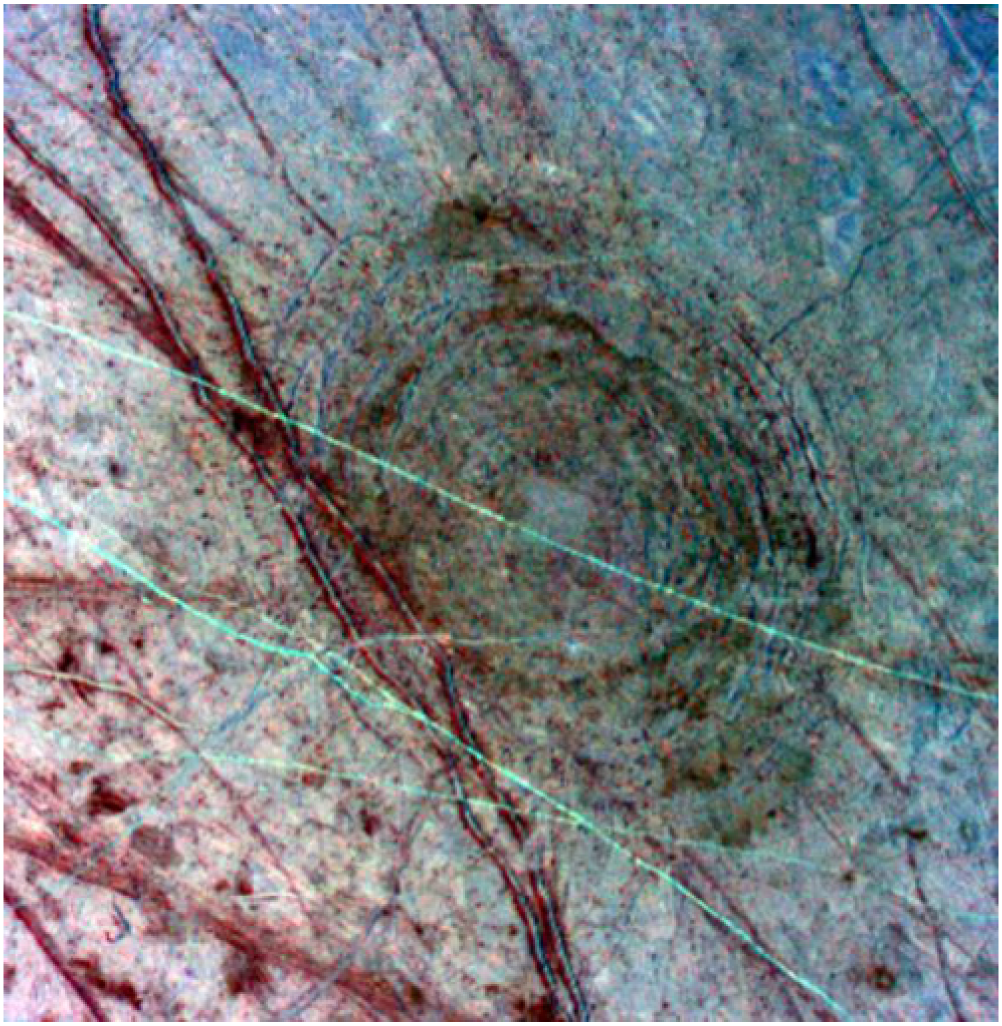
- **Credit: NASA**



Rampart Crater on Mars

The ejecta deposits around the impact crater Yuty (18 kilometers in diameter) consist of many overlapping lobes. Craters with this type of ejecta deposit are known as rampart craters. This type of ejecta morphology is characteristic of many craters at equatorial and midlatitudes on Mars but is unlike that seen around small craters on the Moon. This style of ejecta deposit is believed to form when an impacting object rapidly melts ice in the subsurface. The presence of liquid water in the ejected material allows it to flow along the surface, giving the ejecta blanket its characteristic, fluidized appearance.

- **Credit: NASA**



Ancient Impact Basin on Europa

The “bulls-eye” pattern appears to be a 140-kilometer- (86-mile)-wide impact scar (about the size of the island of Hawaii) which formed as the surface fractured minutes after a mountain- sized asteroid or comet slammed into Europa. This approximately 214-kilometer- (132-mile)-wide picture has had its colors artificially exaggerated to enhance the visibility of features in the image.

North is toward the top of this picture, which is illuminated from sunlight coming from the west. The images were taken on April 4, 1997, at a resolution of 595 meters (1950 feet) per picture element and a range of 29,000 kilometers (17,900 miles). The images were taken by Galileo's solid state imaging (CCD) system.

- **Credit: University of Arizona, NASA/Jet Propulsion Laboratory**